

DURABILITY OF ROCKS UNDER TROPICAL CONDITIONS

LIBRARY
UNIVERSITY OF MORATUWA, SRI LANKA
MORATUWA

MASTER OF PHILOSOPHY

GAN VIDANELAGE INDUTILAK SAMARADIVAKARA



University of Moratuwa, Sri Lanka
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

DEPARTMENT OF EARTH RESOURCES ENGINEERING
UNIVERSITY OF MORATUWA
SRI LANKA

June 2006

University of Moratuwa



85805

85805

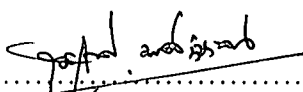
85805

622 '06^u

622(043)

DECLARATION

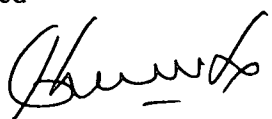
The work included in the thesis in part or whole has not been submitted for any other academic qualification at any institution.



.....
G.V.L. Samaradivakara¹



University of Moratuwa, Sri Lanka
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

Certified


.....
Professor P.G.R. Dharmaratne


.....
Dr. U.G.A. Puswewala

ABSTRACT

Sri Lanka has a basement rock formation of metamorphic origin that the majority is gneissic type, which is intensively used in many of the civil engineering constructions. In addition, foundations of most of the important civil engineering structures are extended up to or into the fresh gneissic rock strata.

Sri Lanka has a tropical climate. Therefore the study on durability of gneissic rocks under tropical conditions would be immensely beneficial to the construction industry of the country.

The simulation of exact natural weathering conditions is quite complicated. This study concentrates mainly on how heat stress affects deterioration of index properties of gneissic rocks.

When the rock mass gets heated, and cooled rapidly due to sudden rainfall, there is a possibility of propagating micro-fractures in the rock mass which will initiate weakening the strength properties of the rock mass.

Most of the bridge abutments and dam constructions are associated with basement rock. In such locations rocks mass is alternately subjected to wetting and drying processes. Therefore the deterioration of rock resulting in its breakup, which is termed as "slaking" is also studied in this research.

One hundred and sixty rock samples of gneissic rock of diameter 54mm (NX size) are tested in this research. Out of these 132 samples are fresh competent rocks and 28 are weathered to different degrees. These samples are selected from biotite gneiss and quartzo-feldspathic gneiss; the major two gneissic rock formations found in Sri Lanka.

Fresh gneissic rock samples were subjected to heating and the weakening of their strength properties were studied upon cooling. Naturally weathered gneissic rock samples belonging to different weathering grades were also tested for their index properties. These were compared with the index properties of artificially weathered fresh gneissic rock samples and some correlations are established.

The rate of deterioration of index properties of quartzo-feldspathic gneiss is seen to be more than that of biotite gneiss. Therefore more attention should be paid in the designing of foundations of important civil engineering structures in quartzo-feldspathic gneiss as far as the durability is concerned, based on the project location.

PREFACE

This report is on “Durability of rocks under tropical conditions”. The report is presented in six chapters.

Chapter 1 briefly describes rock formations of Sri Lanka, weathering of rocks and also the importance of this study. This chapter also includes the hypotheses and the objectives of the research.

The methodology adopted and the instruments used in this study are described in Chapter 2.

Chapter 3 describes the initial study on thermal sensitivity of gneissic rocks.

The detailed studies carried out on the thermal sensitivity of biotite gneiss and quartzo-feldspathic gneiss are described in Chapter 4 and 5 respectively.

The concluding remarks and recommendations are given in Chapter 6.

ACKNOWLEDGEMENT

It is my great pleasure to convey my heartiest gratitude to Professor P.G.R. Dharmaratne and Dr. U.G.A. Puswewala of the Faculty of Engineering, University of Moratuwa, as my project supervisors for their continuous guidance and invaluable support extended to me to complete this research.

I also wish to convey my thanks to Professor (Mrs.) N. Ratnayake, Head, Dept. of Civil Engineering for granting permission to use laboratory facilities of the Department of Civil Engineering.

The great assistance given by Eng. Jayantha Dharmaratne, the Quarry Manager of Lanka Quarries (Pvt) Ltd., in the form of providing necessary facilities to collect samples from their quarry sites is highly appreciated.

I also wish to express my gratitude to Eng. W.A.A.W. Bandara, Director, Engineering and Laboratory Services (Pvt) Ltd., for facilitating laboratory testing, and some of them free of charge.

Finally, I gratefully acknowledge the cooperation given by the laboratory staffs of the Department of Civil Engineering and the Department of Earth Resources Engineering, University of Moratuwa to make this project a success.

*University of Moratuwa,
Moratuwa,
Sri Lanka.*

G.V.I. Samaradivakara

June' 2006

CONTENTS

	<i>Page No.</i>
Declaration.....	I
Abstract.....	II
Preface.....	III
Acknowledgement.....	IV
List Abbreviations.....	VII
List if Tables.....	VIII
List of Figures	X
 <u>CHAPTER 1: INTRODUCTION</u>	
1.1 General Introduction.....	1
1.2 Literature Review.....	1
1.3 Rock formations in Sri Lanka.....	2
1.4 Gneissic rocks.....	2
1.5 Weathering of rocks.....	4
1.6 Rock mass classification.....	5
1.7 Hypotheses.....	7
1.8 Objectives.....	7
 <u>CHAPTER 2: METHODOLOGY</u>	
2.1 Selection of rock samples.....	8
2.2 Sample preparation for testing.....	9
2.3 Heat treatments.....	11
2.4 interpretation of data.....	11
 <u>CHAPTER 3: INITIAL STUDY ON</u> <u>THERMAL SENSITIVITY OF GNEISSIC ROCKS</u>	
3.1 Selection and testing of rock samples.....	12
3.2 Testing program.....	13
3.3 Dry density	14
3.4 UCS of intact rock.....	26
3.5 Slake durability index of rocks.....	36
3.6 The summary of initial study.....	42
3.7 Discussion on the results of the initial study.....	44
3.8 Normalizing of initial test results.....	46
3.9 Discussion on normalized test results.....	57
 <u>CHAPTER 4: DEATAILED STUDY ON</u> <u>THERMAL SENSITIVITY OF BIOTITE GNEISS</u>	
4.1 Introduction.....	59
4.2 Sample preparation.....	59
4.3 Testing of samples.....	59
4.4 Discussion on the results.....	80

**CHAPTER 5: DEATAILED STUDY ON THERMAL SENSITIVITY OF
QUARTZO-FELDSPATHIC GNEISS**

5.1	Introduction.....	83
5.2	Sample preparation.....	83
5.3	Testing of samples.....	84
5.4	Discussion on the results.....	98

CHAPTER 6: SUMMARY OF DISCUSSIONS AND CONCLUSIONS

6.1	The summary of discussion on the results of the initial study.....	99
6.2	The summary of discussion on the results of the detailed investigation on thermal sensitivity of biotite gneiss.....	99
6.3	The summary of discussion on the results of the detailed investigation on thermal sensitivity of quartzo-feldspathic gneiss.....	100
6.4	Comparison of test results of the detailed investigation done on biotite gneiss and quartzo-feldspathic gneiss.....	101
6.5	Conclusions and Recommendations.....	106
References		107



LIST OF ABBREVIATIONS

<i>Abbreviation</i>	<i>Description</i>
BG	Biotite Gneiss
QFG	Quartzo-Feldspathic Gneiss
UPV	Ultrasonic Pulse Velocity
UCS	Unconfined Compressive Strength
SI	Slake durability Index
ASTM	American Standards of Testing and Materials
BS	British Standards
ISRM	International Society of Rock Mechanics



LIST OF TABLES

<i>Table No.</i>	<i>Description</i>	<i>Page No.</i>
1.1	The rock mass rating (geomechanics classification of rock masses)(After Bieniawski, 1989)	6
3.1	Dry density of rocks (After Anon, 1979)	14
3.2	Dry density of fresh biotite samples at room temperature	15
3.3	Dry density of fresh biotite samples after heat treatments	15
3.4	Dry density of fresh quartzo-feldspathic gneiss at room temperature	20
3.5	Dry density of fresh quartzo-feldspathic gneiss after heat treatments	20
3.6	UCS classification given by ISRM (anon, 1981)	26
3.7	UCS of fresh biotite gneiss samples	27
3.8	UCS of fresh biotite gneiss samples after heat treatments	27
3.9	Sketches of the fractured fresh biotite gneiss samples	28
3.10	UCS of fresh quartzo-feldspathic gneiss at room temperature	31
3.11	UCS of fresh quartzo-feldspathic gneiss after heat treatments	31
3.12	Sketches of the fractured fresh quartzo-feldspathic gneiss samples	32
3.13	Gamble's Slake Durability Classification	36
3.14	Slake durability index of fresh biotite gneiss samples	37
3.15	S.I drop of fresh biotite gneiss samples	37
3.16	Percentage S.I drop of fresh biotite gneiss samples	37
3.17	Slake durability index of fresh quartzo-feldspathic gneiss samples	39
3.18	S.I drop of fresh quartzo-feldspathic gneiss samples	39
3.19	Percentage S.I drop of fresh quartzo-feldspathic gneiss samples	39
3.20	Mean values of index properties of fresh BG and QFG	46
3.21	Normalised temperature reference chart	46
3.22	Normalised UCS values of fresh BG after heat treatments	48
3.23	Normalised UCS values of heat treated naturally decomposed BG samples	48
3.24	Normalised UCS values of naturally decomposed BG samples, tested at room temperature	48
3.25	Normalised UCS values of heat treated naturally decomposed QFG	50
3.26	Normalised UCS values of naturally decomposed QFG samples, tested at room temperature	50
3.27	Normalised S.I values of heat-treated fresh BG	52
3.28	Normalised S.I values of fresh BG at room temperature	52
3.29	S.I of highly decomposed biotite gneiss	53
3.30	Normalised S.I. values of heat treated naturally decomposed BG samples	53
3.31	Normalised S.I. values of heat treated naturally decomposed BG samples, at room temperature	53
3.32	Normalised S.I values of fresh QFG	55
3.33	Normalised S.I values of heat treated fresh QFG samples	55

<i>Table No.</i>	<i>Description</i>	<i>Page No.</i>
4.1	Normalised temperature reference chart(For detailed study)	60
4.2	Fresh BG samples prepared for testing	61
4.3	Naturally decomposed BG samples prepared for testing	62
4.4	Ultrasonic velocity and coefficient of weathering (After Bell, 1994)	63
4.5	UPV of non-heat treated fresh biotite gneiss samples	64
4.6	UPV of naturally weathered BG samples	66
4.7	The summary of UPV of naturally weathered BG samples	66
4.8	UPV of heat treated fresh BG samples	67
4.9	UCS of naturally weathered BG	69
4.10	the summary of the UCS of naturally weathered biotite gneiss	69
4.11	UCS of heat treated fresh BG	70
4.12	Sketches of the fractured fresh quartzo-feldspathic gneiss samples	71
4.13	Sketches of the naturally decomposed fresh quartzo-feldspathic gneiss samples	72
4.14	S.I of naturally weathered BG	74
4.15	The summary of S.I of naturally weathered BG	74
4.16	S.I of heat –treated fresh BG samples	75
4.17	Modified table of Table 4.4	80
4.18	The summary of deterioration of BG with respect to UPV	81
4.19	The summary of deterioration of BG with respect to UCS	81
4.20	The summary of deterioration of BG with respect to S.I	82
5.1	Fresh QFG samples prepared for testing	85
5.2	Naturally decomposed QFG samples prepared for testing	86
5.3	UPV of naturally decomposed QFG	87
5.4	UPV of heat treated fresh QFG	88
5.5	UCS of naturally decomposed QFG	90
5.6	UCS of heat treated fresh QFG	91
5.7	Sketches of the fractured fresh heat treated QFG samples	92
5.8	Sketches of the fractured fresh naturally decomposed QFG samples	93
5.9	S.I of naturally decomposed QFG	95
5.10	S.I of heat treated fresh QFG	96
6.1	Comparison of normalized index values obtained for biotite gneiss	100

LIST OF FIGURES

<i>Figure No.</i>	<i>Description</i>	<i>Page No.</i>
1.1	Rock formations in Sri Lanka	03
2.1	A photograph taken from the South end of the site	08
2.2	Selection of naturally weathered BG samples on the quarry face	09
2.3	Rock coring using "HILTY" rock coring machine	10
2.4	Rock cutting using Electric driven masonry saw	11
3.1	Initial sample testing program	13
3.2	Dry density drop vs. Temperature (For fresh BG samples)	16
3.3	Regression plot of Dry density drop vs. Temperature, (For fresh BG samples)	17
3.4	Percentage Dry density drop vs. Temperature for fresh BG	18
3.5	Regression plot of %Dry density drop vs. Temperature, (For fresh BG samples)	19
3.6	Dry density drop vs. Temperature (For fresh QFG samples)	21
3.7	Regression plot of Dry density drop vs. Temperature (For fresh QFG samples)	22
3.8	Percentage Dry density drop vs. Temperature for fresh QFG	23
3.9	Regression plot of %Dry density drop vs. Temperature for QFG	24
3.10	Percentage Dry density drop vs. Temperature (A comparison)	25
3.11	Percentage UCS drop vs. Temperature for BG	29
3.12	Regression plot of %UCS drop vs. temperature for BG	30
3.13	Percentage UCS drop vs. Temperature for QFG	33
3.14	Regression plot of %UCS drop vs. temperature for QFG	34
3.15	Percentage UCS drop vs. Temperature (comparison of BG and QFG)	35
3.16	Percentage Id drop vs. temperature for BG	38
3.17	Percentage Id drop vs. temperature for QFG	40
3.18	Percentage Id drop vs. temperature (comparison of BG and QFG)	41
3.19	Comparison of dry density drop	42
3.20	Comparison of %dry density drop	42
3.21	Comparison of %UCS drop	43
3.22	Comparison of slake durability index	43
3.23	Depth vs. UCS (comparison of BG and QFG)	43
3.24	Depth vs. slake durability index (comparison of BG and QFG)	43
3.25	UCS (Normalised) vs. Temperature (Normalised) for heat-treated BG	49
3.26	UCS (Normalised) vs. Temperature (Normalised) for fresh QFG	51
3.27	S.I (Normalised) vs. Temperature (Normalised) for BG	54
3.28	S.I (Normalised) vs. Temperature (Normalised) for QFG	56
3.29	Collapsing of moderately decomposed BG samples above 600°C	57

<i>Figure No.</i>	<i>Description</i>	<i>Page No.</i>
4.1	UPV (Normalised) vs. Temperature (Normalised) for BG	68
4.2	UCS (Normalised) vs. Temperature (Normalised) for BG	73
4.3	S.I (Normalised) vs. Temperature (Normalised) for heat treated fresh BG	76
4.4	Selection of slices of rock from cylindrical rock core specimens for the preparation of thin sections	77
4.5	Comparison of thin sections prepared using the cross sections of the rock core samples 2B/36(Non-heat treated) and 2B/37(Heat treated)	78
4.6	Comparison of thin sections prepared using the longitudinal sections of the rock core samples 2B/36(Non-heat treated) and 2B/37(Heat treated)	79
5.1	Core samples prepared from the naturally weathered samples of QFG	84
5.2	UPV (Normalized) vs. Temperature (Normalised) for QFG	89
5.3	UCS (Normalized) vs. Temperature (Normalised) for QFG	94
5.4	S.I (Normalised) vs. Temperature (Normalised) for heat treated fresh QFG	97
6.1	Temperature vs. Normalised Temperature	102
6.2	UPV (Normalised) vs. Temperature (Normalised) - A comparison of BG and QFG	103
6.3	UCS (Normalised) vs. Temperature (Normalised) - A comparison of BG and QFG	104
6.4	S.I (Normalised) vs. Temperature (Normalised) - A comparison of BG and QFG	105

